Maintaining Reduced Noise Levels in a Resource-Constrained Neonatal Intensive Care Unit by Operant Conditioning

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Objective: To evaluate the efficacy of operant conditioning in sustaining reduced noise levels in the neonatal intensive care unit (NICU)

Design: Quasi-experimental study on quality of care.

Setting: Level III NICU of a teaching hospital in south India.

Participants: 26 staff employed in the NICU. (7 Doctors, 13 Nursing staff and 6 Nursing assistants).

Intervention: Operant conditioning of staff activity for 6 months. This method involves positive and negative reinforcement to condition the staff to modify noise generating activities.

Main outcome measures: Comparing noise levels in decibel: A weighted [dB (A)] before conditioning with levels at 18 and 24 months after conditioning. Decibel: A weighted accounts for noise that is audible to human ears.

Results: Operant conditioning for 6 months sustains the reduced noise levels to within 62 dB (A) in ventilator room (95% CI: 60.4 – 62.2) and isolation room (95% CI: 55.8 – 61.5). In the pre-term room, noise can be maintained within 52 dB (A) (95 % CI: 50.8 – 52.6). This effect is statistically significant in all the rooms at 18 months (P = 0.001). At 24 months post conditioning there is a significant rebound of noise levels by 8.6, 6.7 and 9.9 dB (A) in the ventilator, isolation and pre-term room, respectively (P=0.001).

Conclusion: Operant conditioning for 6 months was effective in sustaining reduced noise levels. At 18 months post conditioning, the noise levels were maintained within 62 dB (A), 60 dB (A) and 52 dB (A) in the ventilator, isolation and pre-term room, respectively. Conditioning needs to be repeated at 12 months in the ventilator room and at 18 months in the other rooms.

Key words: *India, Noise, NICU, Operant conditioning.*

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Continuous noise levels more than 50 dB - A weighted [dB (A)] in the neonatal intensive care unit (NICU) has a strong correlation with tachycardia, tachypnea and hypoxia in the neonate, after adjusting for other confounding factors [1]. Exposure to noise levels more than 70 dB (A) is associated with two times higher risk to develop mild hearing loss, retardation of intelligence development, periventricular hemorrhage and leukomalacia compared to those in a low noise NICU [2]. In view of these hazards, the average and peak noise levels in neonatal intensive care units (NICU) are not to exceed 50 dB (A) and 70 dB (A), respectively [3]. Noise reduction protocols have been able to bring down noise levels to within 60 dB (A) in NICUs during the implementation period [4, 5]. It is critical that the reduced noise levels are sustained over a long period of time after the implementation of these protocols. A single study has reported sustained reduction of NICU noise at the end of 1 year, using noise sensor light alarms [6].These techniques are expensive and will raise the cost of care in resource constrained settings of developing nations. There is a need to look for less expensive and less labor intensive methods to sustain noise reduction. We conducted a study to evaluate the effect of a simple, low-cost method employing operant conditioning for 6 months in maintaining reduced noise levels in the NICU at 18 and 24 months post-conditioning.

METHODS

A quasi-experimental quality of care study was conducted in a level III NICU of South India from June 2008 to October 2010. The study was carried out in the Ventilator, Isolation, and Preterm rooms. The dimensions of these rooms (length x breadth x height in feet) are as follows - ventilator room: 41.3 × 19.9 × 8, isolation room: 12.8 × 13.7 × 8 and pre-term room: 29.5 × 41.3 × 8. Plastered brickwork partitions rising 4 feet from floor level and continued by glass panels up to the ceiling separate the rooms from each other. The average number of neonates at a given point of time in each of these rooms is as follows - ventilator room: 10 (range: 11-13) , isolation room: 3 (range 2-4), pre-term room: 15 (range: 13- 20).

The guidelines outlined in Standards for Quality Improvement Reporting Excelle2nce (SQUIRE) are used to report this study [7]. The institutional ethical review board approved the study. Informed written consent was taken from the NICU staff.

Noise reduction protocol

From May-June 2007, a noise reduction protocol was established to achieve a noise level within 60 dB (A) in the ventilator room and 54 dB (A) in the isolation and Preterm room [5]. The key behavioral modifications implemented were speaking in low tones, avoiding shouting across the room except during an emergency, holding discussions in a separate room, handling trays and metallic objects gently, putting off the FM radio system, keeping volume of phone at minimum, and tuning alarm volumes using a sound pressure level meter to emit a maximum of 55 dB. Syringe pump alarms were unchangeable so they were put off as soon as possible after rectifying the error. The main environmental changes were fitting of all furniture legs with rubber shoes, replacing metal folders with plastic ones, lubricating the wheels of movable equipment and redesigning the entire NICU during January to May 2008. The entire layout of the NICU was altered to isolate the noise generating utility areas like cleaning room, linen delivery room and storage room from the service provision areas. They were in the centre of the NICU, in the previous design.

In the renovated NICU, from 1-30 June, 2008 noise levels were measured. Sound measurement protocol consisted of a sound pressure level meter with data storage capacity of 32,000 noise recordings was used to record the integrated mean level at the center of the room, every minute for the whole day for 2 months.

Operant conditioning protocol

For 6 months, commencing from August 2008 till January 2009, the noise levels were recorded. Every week the average noise levels were displayed on a board. In weekly staff meetings, a senior staff reinforced the need to maintain the behavior modifications as per the protocol. We did not add any new ventilators or equipments during the study period. Four staff (2 doctors and 2 Nursing staff) who changed during the study period at different points of time (median time: 1 year) were conditioned at the time of joining and further reinforced during the weekly staff meetings held every Friday. The time for the new staff to get conditioned could have increased the noise levels during the transition phase, nevertheless this aspect is very difficult to quantify as the staff changed at different periods of time. As the flux was very small we did not expect this to influence the results significantly. The noise level was measured between September-October 2010 (18 months) and March-April 2011 (24 months). There was no reinforcement during this time.

The sound pressure level meter EQ-8852 [HTA instruments, Bangalore, range of measurement: 30-130 dB (A), accuracy: 1.5dB] was calibrated using standard sounds. This ensured the validity of measurement. A software based calculator computed the geometric mean

Statistical analysis: 5,18,400 samples of noise were collected. This sample size ensures detection of at least 4 dB (A) differences in the repeated measurements with 99% power at 5% level of significance. The standard deviation of the mean occupancy in each room over the study period was 2.1. This ensured representative sampling.

Geometric mean along with standard error (SE) was used to calculate summary measures. Assumptions of normality were tested using the Kolmogorov Smirnov tests before summarizing using mean and SE. The average noise levels were compared between the following four points of time: Before the conditioning (Baseline), During the conditioning, 18 Months after the conditioning, and 24 months after conditioning.

Repeated measures ANOVA (analysis of variance) were used to test the significance of the difference in measurements. Reduction of noise levels to 60 dB (A) or less was considered clinically significant. Difference of 4 dB (A) or more between the means of two sets of readings were considered as clinically significant, as a 4 dB (A) reduction has shown clinically relevant changes in the neonate [8]. $P<0.05$ was considered as statistically significant. 95% confidence intervals were calculated for change in the noise levels at different time points of measurement. Statistical package for social sciences (SPSS16) and n-master software were used for analysis.

RESULTS

***Table* I** shows the noise level measurements in the ventilator, isolation and preterm room, respectively. The baseline noise level increased by 8.9, 1.2 and 2.6 dB (A) above the levels achieved during the implementation phase of the noise reduction protocol in the ventilator, isolation and preterm room, respectively. The high rebound of noise in the ventilator room could be due to the staff not adhering to activity modifications of the protocol. Reinforcement by operant conditioning reduced the level to within 60 dB (A) in the ventilator and isolation room. In the preterm room, the levels reduced to within 50 dB (A). These results were highly significant ($P < 0.001$).

WHAT IS ALREADY KNOWN?

- Noise reduction protocols have reduced the sound levels during the intensive implementation phase in neonatal intensive care units.

WHAT THIS STUDY ADDS?

- Operant conditioning of staff activity for a 6-month period repeated every 12 months in the ventilator room and every 18 months in the Isolation and Preterm room can maintain the reduced noise levels.

At 18 months after conditioning, the noise level in the ventilator room was maintained within 62 dB (A). (P<0.001). The effect was less marked in the isolation room at 1.2 (P<0.001).This is probably due to the difference in activity levels between these rooms. In the preterm room, the noise levels were marginally elevated by 1.7 dB (A) above the recommended 50 dB (A). At an effect size of 3.2 and P < 0.001, the effect of operant conditioning in maintaining reduced noise levels is most effective in the preterm room. At 24 months, the noise levels increased by 8.6, 6.7 and 9.9 dB (A) above what was achieved during the conditioning, in the ventilator, isolation and pre-term room, respectively. At 24 months post conditioning, the effect had reduced, warranting another phase of conditioning.

DISCUSSION

In this study, operant conditioning for 6 months has been successful in maintaining the reduced noise level at 18 months after the conditioning. With a good effect size in the ventilator and preterm room, the results can be generalized to other similar NICUs of India. One of the limitations of the measurements may be the Hawthorne effect, which is the staff becoming quiet during the measurement period [9]. The bias due to this effect was limited by employing continuous automated measurements over two months. Noise reduction by 5 dB has been demonstrated by educating the staff in other studies [10, 11]. These studies have not mentioned the sustainability of these measures. One study has recommended constituting a quality control team which will ensure maintenance of noise levels within recommended limits [4]. But the long term effectiveness of these measures have not been documented. Use of noise sensor light alarm has demonstrated sustained noise reduction over a one year period, which is similar to operant conditioning [6]. These tools if employed will increase the cost of care in resource constrained settings of developing nations [5]. In our study, the technique of employing operant conditioning where feedback is given during weekly meetings and displaying the average levels over a week is effective in maintaining reduced noise levels.

At 18 months post conditioning, the noise levels had partially rebounded in all the rooms. The highest rebound was in the ventilator room at 5 dB (A) above the recommended 50 dB (A) and least in the isolation room. Similar results have been demonstrated in the NICU using noise sensor light alarms over 12 months. In these studies the reinforcement was continuous. At 24 months post conditioning, the noise levels had rebounded significantly. There is no study on the long term results of sustaining reduced noise levels in the NICU. Our study clearly demonstrates the extinction of conditioning at 24 months. This warrants another phase of operant conditioning.

We conclude that the reduced noise levels achieved in the NICU by noise reduction protocols can be maintained within 62, 60 and 52 dB (A) in the ventilator, isolation room and preterm room, respectively at 18 months after operant conditioning. In resource constrained settings, a 6 month period of operant conditioning, to be repeated every 12 months in the ventilator room and 18 months in the isolation and preterm room is a feasible alternative to expensive visual noise alarm systems.

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TABLE I NOISE LEVELS (dB-A WEIGHTED, SLOW RESPONSE) IN ALL THE ROOMS IN THE NICU

Noise levels: Mean (95 % CI)	*Ventilator room*	*Isolation room*	*Preterm room*
Before conditioning	68.9 (67.1-70.8)	61.2 (59.0-63.4)	56.6 (55.7-57.5)
During conditioning	56.2 (52.8 -59.6)	56.4 (52.1-60.6)	47.3 (46.2-48.4)
18m post-conditioning	61.3 (60.4-62.2)	58.7 (55.8-61.5	51.7 (50.8-52.6)
24 m post-conditioning	64.8 (64.2-65.4)	63.1 (62.2-64.0)	57.2 (56.7-57.7)

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